PAPER

Towards metrology that is automated and integrated in production

All the progress made in terms of digitisation and automation has given rise to unprecedented levels of technological development as regards fitting robots, machines and processes with measuring instruments and advanced use procedures.

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Metrology and integrated sensorics have made it possible to perform real-time monitoring of machines and processes; data can be obtained instantaneously, and control and traceability can be achieved throughout the entire life cycle of a product from the moment of its inception and until it is applied in a real environment.

Thanks to the digitisation of production processes, metrology is no longer considered to be the last link in an industrial process but rather an optimum ally that allows advanced manufacturing to address all the challenges posed by a smart industry model.

The transition is speeding up under the influence exerted by production demands in some of the most relevant industrial sectors: automation and aeronautics.

In the Basque Country, most of the progress made in the area of fundamental research related to precision engineering and metrology to meet these needs is being addressed by the research group featuring Tekniker working in close cooperation with Ideko, Tecnalia, Vicomtech, the University of the Basque Country (UPV/EHU) and IMH Campus.

But what are the main challenges associated with performing metrology activities in a non-controlled digital environment in the case of production resources or processes?

Uncertainty and traceability

In order to understand the significance of this challenge, it would be first necessary to focus on two of metrology's main properties: the allocation of measurement uncertainty and how metrological traceability can be guaranteed.

Measurement uncertainty is technically defined as a "non-negative parameter that characterises the values allocated to a measurand" and allows you to discover the extent of an error whenever measurement outcomes are reported.

As regards metrological traceability, the term refers to "the property by means of which the outcome of a measurement can be related to a reference measurement by means of an uninterrupted and documented chain of calibrations".

Both properties are relatively well controlled whenever metrology is performed in a laboratory setting in a controlled environment, although the same does not apply when this happens in a production environment.

In the case of measurement uncertainties associated with a machine and a process, our challenge consists in minimising them at a reasonable economic cost and, what is even more important, performing quantifications.

Production environments are characterised by a number of variables that constrain metrology during a process due to elements such as temperature, the presence of vibrations or soiling in certain manufacturing processes.

A number of requirements must also be met with regard to response times and there has to be a sufficient level of accuracy to incorporate metrology as an active element in manufacturing processes.

An unprecedented technological development

An unprecedented technological development has been carried out to properly address this challenge and integrate advanced use procedures and measurement instruments in resources and processes.

For instance, new sensors are currently being developed to monitor production processes; processing and measurement procedures are being automated by means of instruments installed on industrial robots and machine tools can be used to perform contact/contactless metrology.

These advances are being supported by research actions whose aim is to ensure uncertainty and traceability metrological properties, as well as to develop new metrological patterns, self-calibration procedures and external metrological frameworks. The above-mentioned R&D agents are also looking into how metrological procedures can be improved and integrated in the control loop of a machine and/or process. New methodologies used to process measurement data quickly and accurately are also being studied.

Artificial intelligence in metrology

There is, however, a scientific-technological challenge that should be mentioned separately and is related to how metrological systems are digitised.

We are making significant efforts to develop models of complex mechatronic systems used to measure objects.

We have carried out this work with a coordinate measuring machine and, more recently, with a robot, a machine tool and measurement sensors to mimic a laser line vision system or camera used for photogrammetry.

High-rigidity mechatronic systems respond well to a purely kinematic model, although in the case of low rigidity models (like robots, for instance), these models have to be supplemented by components to address the lack of rigidity of these systems and cope with a robot's variable operating conditions.

It is in this scenario where new technologies such as artificial intelligence (AI) has come to the forefront and which, based on having suitable characterisation strategies and proper training for staff on how to use IT models, allow us to improve the purely numerical models used until now and combine the best features each one has to offer to develop more accurate "hybrid models".

Achieving a good model is essential to develop the digital twin of a measuring instrument and procedure and to also design optimised measurement strategies.

It could also be helpful to predict the level of uncertainty related to measuring a complex procedure, to feed a twin on a real-time basis as a guide for the measurement process and allocate the uncertainty based on simulations and obtain reliable results in a short period of time so they can be fed back into the manufacturing process.

Future challenges

All of the above together with the capabilities AI can offer when applied to metrology will allow us to contemplate an industrial future in which metrology will not only play an outstanding role but also operate autonomously to eventually supply reliable data so that decisions can be made without human intervention.

In this regard, there are several challenges related to ICTs:

1.- The interoperability of data originating from metrology as addressed by the Quality Information Framework (QIF) initiative.

2.- The integration of metrology in production and business management systems.

3.- The digitisation of calibration and certification processes required for the measurement solutions currently driven by the European Community via a concept called the Digital Calibration Certificate (DCC).

4.- The correlation required, via AI, between production and quality data to advance towards a preventive maintenance model.

5.-Data traceability, regardless of whether they are metrological or not. Nowadays, the use of blockchain technology is being investigated as a decentralised infrastructure organised in block chains.

Some of these challenges are associated with in-process metrological traceability. We understand that these processes will be carried out in-situ with patterns that have not necessarily been calibrated in a laboratory (self-calibrating patterns).

Calibration certificates will be validated digitally and automatically transferred to production management systems to fully guarantee in-process metrology traceability.

We believe that all of the above will allow us to advance towards a much more resilient and sustainable model and that we will witness a new horizon in which it will be possible to achieve optimum consumption levels in terms of materials and energy resources from the perspective of a “zero-defects” approach.

Public-private partnerships, moreover, will be essential to transfer to companies all the knowledge that is produced to have a real impact on the industry and society at large.